

So Why DO You Trust That Model? Some Thoughts on Modeling, Simulation, Social Science and Decision Making

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In the past couple of years, the Advanced Concepts Group has had an ongoing discussion group that investigates the problem of cognition under conditions of uncertainty in high consequence decision environments. Frequently, this line of discussion leads us to consider the role of technology – specifically computational modeling and simulation – in decision problems ranging from intelligence analysis to homeland security to nuclear weapons. A topic that caught our interest early on is the role of computational social simulations – e.g., agent based, social network, or systems dynamics models – as conduits for bringing social science knowledge into application areas like intelligence analysis and homeland security.

In the wake of 9/11, federal agencies have been pouring money into the research and development for a wide range of computational tools and technologies for such applications as enhanced collaboration, computational mining and aggregation for massive datasets, and pattern recognition. Within this technology portfolio, computational modeling and simulation – and in particular, social network and agent based models – seem to have caught the attention of some sectors of the post 9/11 United States national security community. Computational social simulation promises novel and valuable ways of exploring human social behavior. However, it's prudent to ask ourselves what's really required to transform computational simulations of social phenomena into something 'useful.' Taking a closer look at the epistemological and social issues involved in more evolved areas of computational science – such as physics and chemistry – reveals how fraught all simulation tools actually are, and how difficult it can be to develop good analytical tools.

Let's begin by exploring one of the recurrent themes in developing frameworks for analyzing social phenomenon: namely, the idea that **terrorism is an emergent property of a complex system** and is therefore best studied through complexity theory. Thanks to writers like Stephen Wolfram, complexity theory is the sexiest frontier in science. Researchers in fields from economics to anthropology are recognizing that theories of nonlinear systems, complexity and chaos offer attractive and provocative metaphors for thinking about social systems, from the level of small group interactions to large-scale societies. However, complexity theory has yet been adequately operationalized, much less debated, within the larger social science community. With the possible exception of economists and political scientists, few social scientists routinely frame the problems they study in the language – much less the mathematics – of complexity and

chaos. Indeed, most of the computational modeling in social complexity is being pursued by computer scientists, physicists and mathematicians at places like the Santa Fe Institute. How to represent social phenomena in the frames and language of complexity theory is provocative and fascinating, but it is still a very young endeavor. A great deal of cognitive and financial investment is required before this area of research can offer decision makers much in the way of useful theories, analytical tools, models or simulations.

Then there are problems with the application of computational social simulations in high consequence decision areas. In this regard, we can learn a lot from the experience of the national laboratories. Computational methodologies like social network and agent based models bear more resemblance to the codes used in scientific computing than they do to other forms of software – for example, avionics software, operating platforms, or the desktop applications that you use in your day-to-day work. For one thing, social models are used in much the same way that advanced simulations are used; that is, to explore phenomena for which empirical data are hard to come by, and for which experimentation is unwieldy, expensive, or impossible. Moreover, computational social science requires the specification of social theory into models that are then instantiated in a computationally tractable format, so that the theories can be more easily used to generate insights (in their weak form) or to make predictions (in their strong form).

As such, the national laboratories' experience with computational modeling and simulation may offer some valuable lessons about the unforeseen challenges of developing novel computational tools to support high-consequence decision problems. Using some of the insights generated during a decade's worth of investment in scientific computing, let's explore a couple of the themes that characterize the postulated role of computational modeling and simulation for social phenomena:

Computational Models are Predictive under Uncertainty. In scientific computing, the credibility of a family of simulations is composed of three elements: the fidelity of a model's predictions to empirical data; the degree to which the model is robust to all classes of uncertainty; and the accuracy of models in predicting phenomena in regions where experiments haven't been conducted. Researchers like Francois Hemez at Los Alamos have pointed out that there is a trade-off among these three elements. Higher fidelity models are less robust to uncertainty, but models that are more robust to uncertainty are less consistent in their predictions – making them less useful as tools for generating point-specific, actionable predictions.

Computational Models are Tools We Can Develop for a User Community. This metaphor implicitly likens computational models to instruments like a hammer or a chisel, tools whose use-value is clear regardless of context or experience. You don't need to know a lot about the hammer's construction to use it productively. However, scientific models run the gamut from black box to glass box, with those at the latter end of the continuum requiring the user to have intimate knowledge about the guts of the model before it can be used productively. Most scientific models are complicated constructions in which knowledge (in the form of theories) undergoes multiple transformations before it's instantiated in a working program. In scientific computing, interpreting the model's output in a high consequence decision environment requires considerable cognitive familiarity with the model *and* the subject matter.

Computational Models are More Trustworthy than Human Judgment. Models are representations of a community's current state of knowledge. Users who perceive themselves in high-consequence decision environments may be wary of computational technologies that promise prediction, but whose workings they don't understand. Verification and validation can play a role in identifying drivers for uncertainty and possibly generating greater trust in the model - but also require considerable investment in research activities around the code. The fact remains that human judgment will always be an irreducible component of complex decision making. The belief that computational models can eliminate this role is dangerous.

Despite the energetic discussion around developing computational models to predict social phenomena like terrorism, what is more interesting is the discussion that is *not* taking place: namely, how – and even if – these tools can be used by analysts and decision makers to effect desirable outcomes. After all, computational modeling and simulation capabilities are human-generated artifacts whose utility depends on how people engage them. Viewed through a social lens, modeling and simulation tools – especially very complicated M&S methodologies, such as agent based models rooted in complexity theory – are more fraught than they might appear. Recognizing the issues involved in applying M&S to high consequence decision environments raises important and interesting research issues, such as how to represent social knowledge in computational formats, representing, managing, and communicating uncertainty, how to verify computational social methods, and how to deal with the thorny problem of validation – not to mention questions about what kind of organizational contexts are most conducive to the use of computational tools, and the relationship between model, user, and decision maker. As we invest more money and effort into computational modeling and simulation in *all* areas of knowledge production, these questions are well worth asking.